Dry Bin Filler for Apples

D. L. Peterson, A. L. Tabb, T. A. Baugher, K. Lewis, D. M. Glenn

Abstract. *A unique dry bin filler for apples using a sequenced tray was developed to reduce bruising in packing operations. Research and commercial trials in West Virginia, Pennsylvania, and Washington State demonstrated the ability to fill bins evenly and with low damage. Cultivars with different bruising susceptibility ('Pink Lady,' 'Golden Delicious,' 'McIntosh,' 'Mutsu,' 'Delicious,' and 'Fuji') were used to test the bin filler in research trials and commercial assessments. Fruit that were downgraded from U.S. Extra Fancy grade after handling by the bin filler were 1.7%, 1.4%, and 2.9% at each test location. The filler was shown to produce less than 5% bruising on fruit and to have the ability to operate in commercial locations.*

Keywords. *Dry bin filler, Apples, Fruit, Quality, Fruit handling, Fruit bruising.*

Bulk bins are used in the tree fruit industry for transport of fruit from the field and handling and storage in packing facilities. Automated fruit packing lines deliver fruit to bulk bins via conveyor belts; a mechanical device called a bin filler is needed to transfer the fruit from the conveyor belt to the bulk bin. Commercial bin fillers for packing lines are expensive and bruise fruit excessively (Lott, 2008; Robinson, 2008). Bin fillers are not currently used in harvest operations; however, with the growing interest in semi-automated harvest, there is a need for an in-field dry bin filler that efficiently handles fruit at acceptable quality standards.

We developed a unique dry bin filler for handling fresh fruit. The objective of this article is to describe the design of the bin filler and to evaluate its operation and damage level. No attempt was made to quantitatively compare the bin filler described in this article with any other experimental or commercial bin filler.

Materials and Methods

Generally, there are two types of bin fillers, wet and dry. Wet bin fillers use water to gently place the fruit in bins. The dry type uses a mechanical method to deliver the fruit from the conveyor to the bin; the most common systems use a rotary delivery system. There are a number of wet and dry bin fillers available (Diener and Fridley, 1983; Cargill and Rehkugler, 1983; O'Brien and Gaffney, 1983; Powell, 1978; Myers and Sheetz, 1980; Stilwell and Westerling, 1981; Jesperson and Jesperson, 1990; Main and Main, 1997; Main, 1998; Peterson and Wolford, 2003; Aweta Autoline, Reedley Calif.; Durand-Wayland Inc., LaGrange, Ga.; Greefa, Geldermalsen, The Netherlands; MAF Industries, Inc., Traver, Calif.; Munckhof, Oliver, BC, Canada). There are difficulties with either type of bin filler. While wet fillers limit fruit damage, they are expensive, take up a lot of space, and because water is involved, have the potential to spread disease inoculum from infected to non-infected fruit. In most cases, the latter requires a post-harvest chemical dip, which in turn, results in risks associated with food safety and wastewater management. Dry bin fillers avoid the disease problem, but produce more damage to the fruit in the process of delivery from the conveyor to the bin (Zhang and Hyde, 1992b; Hyde, 1997).

As each bin filler type has advantages and disadvantages, the choice as to which bin filler to choose then depends on the physical constraints of the packing facility and the preferences of management. In order to clearly present the advantages and disadvantages of our bin filler, we decided on two types of evaluation criteria: operational performance and fruit quality performance.

The operational performance criterion consists of three areas: fill uniformity, fill rate, and the incidence of malfunction. A bin filler with ideal fill uniformity places fruit in the bin such that one full layer covers the bottom, and then the next layer fully covers the first layer, and so on until the bin is completely filled; the top layer of fruit should be parallel to the ground. Uniform filling is desired for two reasons. The first is that bins should be filled to capacity without overfilling in order to keep the total number of bins to a minimum and allow the stacking of filled bins one on top of the other. The second is that if the filler does not evenly fill the bin by either mounding (there are more fruit in the center than on the edges of the bin) or creating a depression (there are more fruit near the sides of the bin than in the center of the bin), the fruit may roll and create fruit-to-fruit contacts, which may cause bruising. In order for a bin filler to keep up with the fruit being delivered by the conveyor, the filler must

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have a suitable fill rate. Finally, bin fillers must operate at a high degree of precision and accuracy with a minimal amount of human adjustment; we call this characteristic incidence of malfunction.

The fruit quality performance criterion consists of a bin filler's ability to take fruit from the conveyor belt and deliver that fruit into the bin without inflicting damage, either from machine, bin, or fruit-to-fruit impacts. The degree of damage, and of what kind, is necessary for evaluating a bin filler's impact on fruit packout. Besides damage from physical impacts, another part of this criterion is whether or not the filler aids in the spread of disease, such as when the filler uses water.

Machine Design

Since one of the problems of rotary delivery dry bin fillers is non-uniform fill, a goal of the machine design was to create a dry bin filler that demonstrated uniform filling. To accomplish this goal, our bin filler loads fruit from the conveyor onto a rectangular tray. Once the tray is filled, it is lowered into the bin; when the tray is a small distance from the bottom of the bin or the last layer of fruit, the tray releases the fruit. The three main components of the bin filler are: the accumulating area, the fruit transfer incline, and the sequenced tray (see figs. 1-3).

The fruit on the conveyor belt arrive at the bin filler in a random distribution. The function of the accumulating area is to organize fruit delivered by the conveyor into a single tight layer, or matrix-like arrangement, in which fruit-to-fruit impact is minimized. The accumulating area accomplishes this organization by a series of parallel, rotating, roller brushes where fruit are accumulated in rows and incoming fruit advance the rows (the brushes are similar to those used in fruit washers and waxers.). In order to distribute the fruit to all columns of the matrix-like arrangement, the last several roller brushes are helixes (starting at the center, half clockwise, half counter clockwise) to ensure that fruit are fully distributed along the width of the accumulating section. If the feed conveyor is narrower than the width of the roller brushes, stationary panels help to direct the fruit to the full width of the roller brushes (fig. 4). The bin model used was MacroBin 28-FV (Macro Plastics Inc., Fairfield, Calif.) with

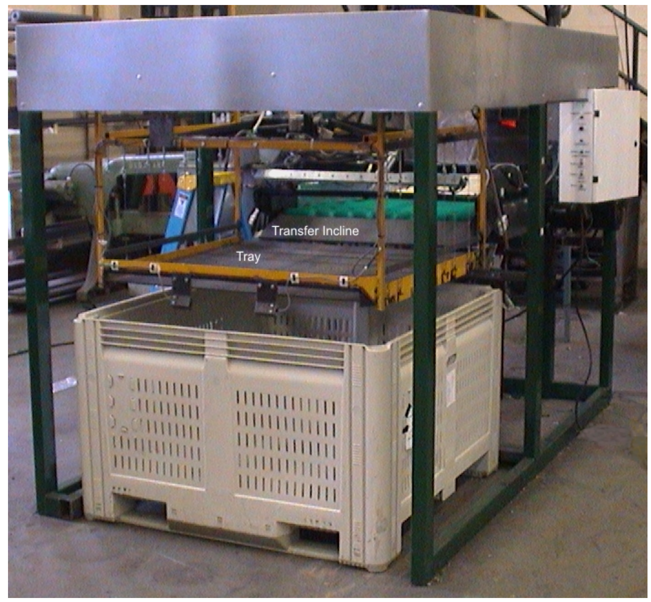

Figure 1. Overview of bin filler.

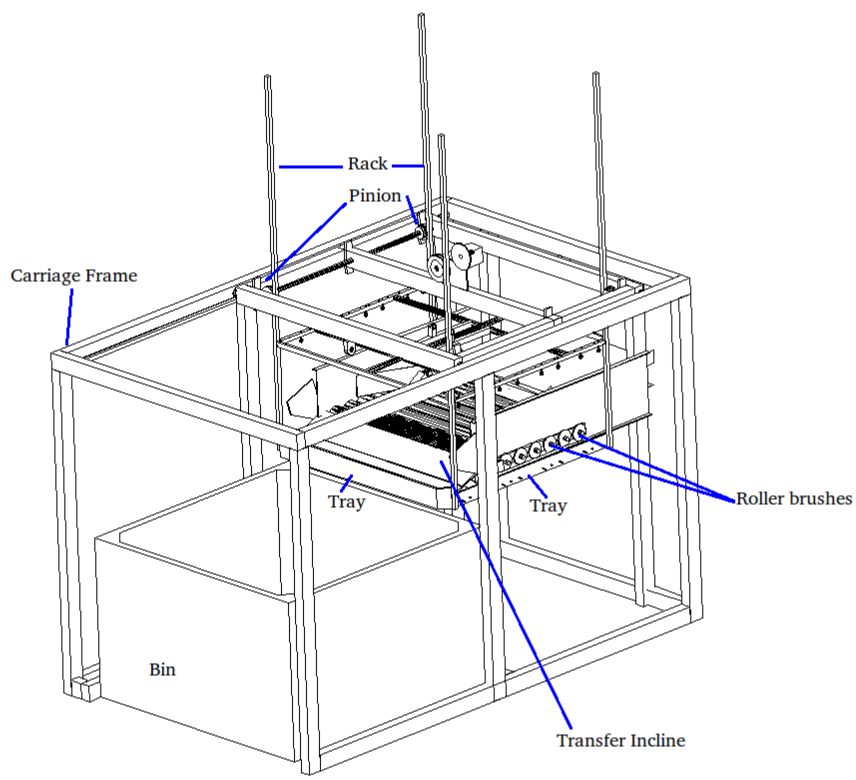

Figure 2. Labeled overview of the bin filler.

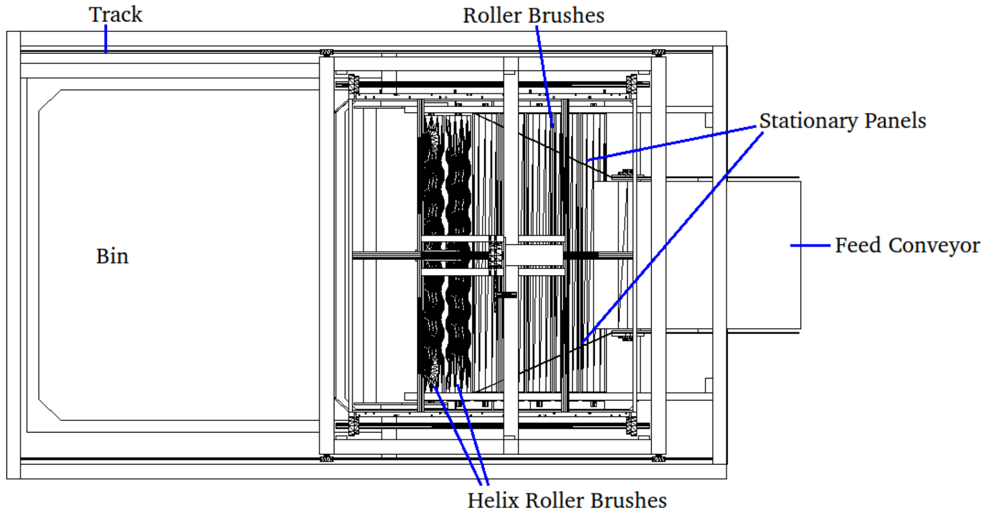

Figure 3. Overhead view of the bin filler.

outside dimensions of 124 (L) × 124 (w) × 78 (h) cm and a load capacity of 566 kg.

From the accumulating area, the fruit then travel down a transfer incline and are deposited into the tray (figs. 5 and 6). The tray is supported by a rack and pinion arrangement, which in turn is supported by a carriage frame. The carriage frame is guide wheel supported on a track, which confines the positioning of the tray, as shown in figure 6. The rectangular tray has boundaries on three sides; in figure 3, the boundaries are on the top, bottom, and left sides of the tray. The rightmost side of the tray has no boundary. The tray boundaries and the tray itself should be covered with foam to reduce fruit impacts. One of the tray's sides (see fig. 5) is initially positioned close to the lower edge of the transfer incline. At this point, the majority of the tray is under the roller brushes. As the fruit feed into the tray, a linear array of 14 optical

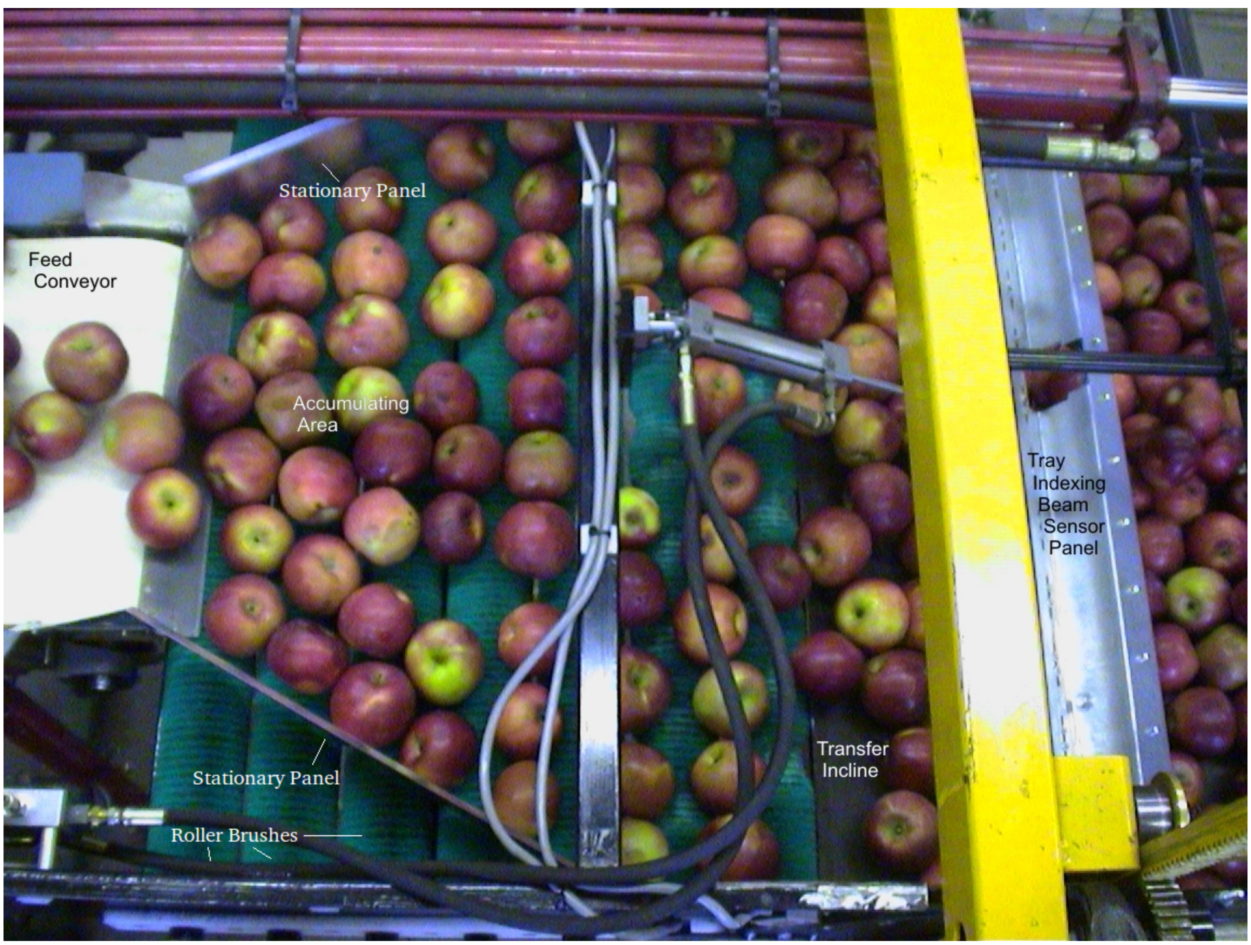

Figure 4. Overhead view of accumulation section.

proximity sensors, spaced 6.985 cm (2.75 in.) apart (miniature self-contained dc photoelectric sensors, Q10AN6D, Banner Engineering, Minneapolis, Minn.) serve as tray indexing beam sensors. They are positioned above the upper edge of the transfer incline to determine when fruit are occupying that area. When all the sensors detect fruit, a linear actuator is activated to translate the tray away from the transfer incline until at least one of the optical proximity sensors is not detecting fruit. The process is repeated until the tray is full, and then a cycle is initiated to place the fruit into the bin.

A standard roller limit switch, which senses the position of the carriage frame, determines when the tray is full. When this limit switch is engaged, the roller brushes, and optionally, the feed conveyor are deactivated, the transfer incline is tilted upward to a level position in order to stop fruit transfer, and then the carriage is shifted such that it is centered above the bin. As the transfer incline is tilted upward, a barrier is

Figure 5. Fruit transfer section and tray.

Figure 6. Carriage frame and supports.

positioned to prevent fruit from rolling off the end of the tray that has no built-in boundary. Note that one side of the tray has to be open or else the tray would not fit under the roller brushes. As the carriage frame is shifted over the bin, another limit switch is engaged to deactivate the tray fill cycle and initiate the tray dump cycle. The tray is lowered into the bin by the rack and pinion drive until either a limit switch sensing the rack position (for the first dump when the bin is empty) or the bin depth sensors (Ultrasonic Proximity Sensor 30N1703, Baumer Ltd. USA , Southington, Conn.) sense fruit. At this point, the tray is ready to deposit fruit into the bin (fig. 7).

The tray bottom is made up of hinged panels; the panels are in the closed position when the panels are horizontally oriented, and open when they are vertically oriented (fig. 8). The panels are held closed by cables. Once the tray is in position to deposit fruit, a linear actuator is extended to release the tension in the cables, and the rack and pinion drive is reversed to raise the tray. As the tray is raised, the hinged panels open and as a result the fruit are carefully placed into the bin. When the tray is fully raised, the linear actuator is reversed to bring the hinged panels back to their closed position, and then the carriage and tray are repositioned to their initial positions and the complete cycle is repeated until the bin is filled.

Figure 7. Overhead view of placing fruit into the bin.

Figure 8. Hinged tray bottom shown in partially open position.

Experiments were conducted at three locations: the laboratory, a commercial packing line in Pennsylvania, and a commercial packing line in Washington State. Each experiment had similar testing procedures so that the data were comparable. The results were evaluated against the fill uniformity, fill rate, and the incidence of malfunction criteria previously described. Apples were inspected for bruise incidence and severity, with bruise severity determined by measuring bruise diameter. Fruit grade classes for various bruise specifications (diameter of individual bruises or area of multiple bruises) were determined based on USDA Grades and Standards (table 1).

Experiment 1

The first experiment was performed at the Appalachian Fruit Research Station (Kearneysville, W.V.) during the fall of 2005. Four apple cultivars ('Golden Delicious,' 'Suncrisp,' 'Pink Lady,' and 'McIntosh' which were very carefully hand-harvested at varying stages of maturity and "Extra Fancy" grade) were selected to test the system. On the day of the experiment, fruit firmness and starch index were determined for 10 apples per cultivar. For each bin filler experiment, three replications of 100 apples (called the test fruit) were carefully hand placed onto the feed conveyor along with about 1600 filler apples, from a cultivar with contrasting color or shape. From the conveyor, the mixture of test and filler apples continued through the bin filler. After the experiment, the apples were held at room temperature for 5 or 6 days and then run through a commercial fruit grader so that the test apples could be separated and then carefully graded according to USDA fresh market standards, based on the specifications given in table 1. During the experiment, the time to complete the bin fill was recorded and a visual observation of the uniformity of fill was noted. In addition, the weights of all apples in the bin were recorded for calculating the fill rate. Hand placing the damage-free test apples onto the feed conveyor limited the overall feed rate possible and therefore limited the fill rate. Two additional bins were filled with a faster apple feed rate in order to determine potential optimum fill rate capacity.

Experiment 2

Experiment 2 was conducted at a commercial packing facility (Bear Mountain Orchards, Aspers, Pa.) during March 2008. Experiment 2 closely follows Experiment 1 in methodology, and as such uses the same damage classes as shown in table 1, harvest maturity evaluations, bin fill rates, and fill uniformity. Fruit were carefully pre-graded for brusises, and tests were conducted on three cultivars

Table 1. Classification of bruise damage for Experiments 1 to 3.

No. Assigned to Class	USDA Fresh Market Standard	Bruise Specifications
1	"Extra Fancy"	No bruising
2	"Extra Fancy"	Bruise diameter ≤ 3.2 mm (1/8 in.)
3	"Extra Fancy"	Bruise diameter 3.2 to 6.4 mm (1/ 8 to 1/4 in.)
4	"Extra Fancy"	Bruise diameter 6.4mm (1/4 in.) to 12.7 mm (1/2 in.) or area of several bruises ≤ 127 mm^2
5	"Fancy"	Bruise diameter 12.7 to 19 mm (1/2 to 3/4 in.)
6	Downgraded	Bruises larger than the tolerances in "Fancy"
7	Downgraded	Cuts or punctures of any size

(‘Mutsu,’ ‘Golden Delicious,’ and ‘Delicious’) that have a high to low susceptibility, respectively, to bruising. In addition to conducting general damage assessments, the incidence and type of fruit damage induced by different components of the bin filler were determined. We call the evaluation of fruit damage while being handled by the bin filler the outer-bin tests, as opposed to the inner-bin tests, which sought to determine if placement of fruit within three different regions of the bin (bottom third, middle third, top third) resulted in different levels or types of damage.

For the fruit damage evaluations, apples collected from the conveyor belt constituted the control. Fruit also were collected from four other locations: the accumulation area, and the lower, middle, and top thirds of the bin. For the inner-bin tests, the filler was stopped so that the fruit could be collected. For each of three cultivars, five 20-fruit replicates were collected from each sampling site (conveyor, accumulation area, and three bin locations). Then, the samples were placed on trays for 10 hours at room temperature. Bruise incidence and severity were adjusted against the controls sampled from the packing line belt prior to entering the bin filler.

Experiment 3

The third experiment was conducted at a commercial fruit packing facility (Double Diamond Fruit, Quincy, Wash.) during April 2009. The bin filler was incorporated into the commercial packing line by replacing one of the facility’s rotary bin fillers at the end of the line. The filler was in operation for 36 h (8 h/day for 4 days, plus 4 additional hours).

The fruit used for the fruit damage trials were ‘Golden Delicious’ and ‘Fuji.’ Both cultivars consisted of 42-lb Extra Fancy 80 count fruit that had been sorted, graded, and packed for shipment in boxes of four trays each. The fruit were taken directly from controlled atmosphere (Calif.) storage. The locations of the bin were divided into four quarters: bottom layer, bottom quarter layer, middle layer, and top quarter layer. Prior to the experiment, individual fruit were inspected for bruises, punctures, and cuts, and they were marked with stickers. Fruit were also marked to indicate placement in the bin. Marked (stickered) fruit were put on the commercial line prior to the elevator that transports fruit to the accumulating area. Fruit were placed such that it would be deposited in the four bin positions. After the fill, fruit were removed from the bin, placed back on box trays, and boxes were repacked by hand. These boxes were held at room temperature for 18 h prior to damage assessment. Twenty marked fruit were sampled for each of the four bin sample layers from each of four bins per cultivar. Two trials each of 360 fruit were conducted on both ‘Fuji’ and ‘Golden Delicious.’

After the 18-h holding period, the fruit were inspected for damage. We noticed that one sort of cut or puncture was a result of fruit being cut by the rods in the sequenced tray; these are identified separately in the table of results and are referred to as rod cuts.

Results And Discussion

Experiment 1

We first present the performance of the bin filler with respect to the operational criterion. The typical fill rate was 30 kg/min., which fills a typical bin (381 kg/ 840 lb/ 20 bushels) in 12.7 min or 4.7 bins/h. During the fast feed rate test, one bin had a fill rate of 46.5 kg/min (7.3 bins/h), and the second bin 50.5 kg/min (8 bins/h). Maximizing actuator speed during tray dump would increase fill rate. Uniformity of fill was judged to be acceptable. There was slight under-fill along three sides of the bin. It was felt that this slight under-fill could be minimized or eliminated with minor dimensional modifications of the roller brush width and transfer incline components.

Tables 2 and 3 give a summary of the performance of the bin filler with respect to fruit damage. Fruit quality was generally very good with Extra Fancy grade ranging from 96% for ‘McIntosh’ (over-ripe, 45.4 N firmness, when harvested, and known to be very susceptible to damage) to 99.7% for ‘Pink Lady’ (a more damage-resistant cultivar, 85.5 N firmness when harvested). For all cultivars, moderate to severe bruising to individual apples (Fancy or a lower grade) was not a serious problem. Cuts and punctures were never more than 2.3% and consisted almost entirely of stem punctures.

Analyzing the Extra Fancy apples further showed that most of the bruising was less than 6.4 mm in diameter (almost never more than one bruise/apple) and it was expected that

Table 2. Fruit firmness, fruit maturity, bin fill rate, and fruit grade classification following dry bin filler handling, Experiment 1.

Cultivar								
Filler Apples	Test Apples Evaluated for Damage	Firmness (N)[a]	Starch Index[b]	Fill Rate (kg/min.)	Extra Fancy[c] Classes 1-4 (%)	Fancy Class 5 (%)	Downgraded due to Bruises Class 6 (%)	Downgraded Due to Cuts & Punctures Class 7 (%)
Delicious	Golden Delicious	77.4	6.6		99.3ab	0.0a	0.0	0.7ab
Delicious	Sun Crisp	80.0	7.3		97.7bc	1.0ab	0.0	1.3ab
Enterprise	Golden Delicious	58.3	9.0		98.0ab	0.7ab	0.0	1.3ab
Enterprise	Golden Delicious	63.6	6.7	28.8	98.0ab	0.3ab	0.0	1.7ab
Enterprise	Golden Delicious	63.6	6.7	30.0	99.0ab	0.3ab	0.0	0.7ab
Rome	Pink Lady	88.5	4.4	30.2	99.7a	0.0a	0.0	0.3b
Rome	Pink Lady	88.5	4.4	30.9	99.7a	0.0a	0.0	0.3b
Golden Delicious	McIntosh	45.4	9.0	26.6	96.0c	1.3b	0.3	2.3a

[a] Readings taken with a hand-held Magness Taylor penetrometer fitted with an 11-mm tip.
[b] Harvest criteria: 1-3 is immature, 4-6 is mature, and 7-9 overmature.
[c] Mean separation within columns by Duncan’s multiple range test, P = 0.05.

Table 3. Detailed breakdown of Extra Fancy apples following dry bin filler handling, Experiment 1.

Cultivar	Class 1[a] (%)	Class 2 (%)	Class 3 (%)	Class 4 (%)
Golden Delicious	88.0a	8.0	3.0a	0.3a
Sun Crisp	82.7ab	6.3	6.3ab	2.3ab
Golden Delicious	74.7b	7.0	10.7b	5.7c
Golden Delicious	75.7b	7.7	10.3b	4.3bc
Golden Delicious	82.7ab	6.0	7.7ab	2.7abc
Pink Lady	84.7ab	5.7	8.3ab	1.0ab
Pink Lady	89.7a	4.0	4.3ab	1.7ab
McIntosh	76.3b	7.7	8.0ab	4.0bc

[a] Grade classes described in table 1. Mean separation within columns by Duncan's multiple range test, P = 0.05.

most of these bruises might disappear in storage (a characteristic observed by fruit packers and demonstrated in research trials; Zhang and Hyde, 1992a).

Experiment 2

Evaluations of fill evenness and fill rate are as follows. The fill evenness was uniform with some slight mounding in the center. The fill rate was 6 to 7 bins/h, which caused apples to accumulate at the end of the conveyor. A limited electrical capacity at the packing facility prevented us from testing the bin filler with a larger volume hydraulic system that would have permitted a shorter cycle time.

The results of Experiment 2 showed that over 96% of U.S. Extra Fancy apples will be graded as such after a pass through the dry bin filler (95% level of probability). 'Delicious' fruit, which averaged 68.2 N firmness, graded 97% to 100% U.S. Extra Fancy, and 'Golden Delicious,' which averaged 74.7 N firmness, graded 98.9% to 100% Extra Fancy (tables 4 and 5). Grades for 'Mutsu,' a cultivar with very high susceptibility to bruising, from a lot of fruit that was over mature, 50.7 N firmness, graded 96% when samples were collected from the bottom third of the bin and 98% when fruit were collected from other bin filler locations. Most of the bruising was less than 3.2 mm in diameter, which is Class 2 of U.S. Extra Fancy grade (table 6). Across the three cultivars, there was no significant difference in bruising due to sampling location—the conveyor belt, the accumulation area, or the lower, middle, and top thirds of the bin.

Experiment 3

First, we discuss the performance of the bin filler on operational criteria, and then the procedures for the fruit damage tests. The filler performed without problems for the entire test duration. The fill rate was timed when there was a continuous flow of fruit from the conveyor. The fill times ranged from 6.9 to 8 bins/ h. This rate was deemed acceptable by current industry standards and for this specific packing line and run. It was suggested that this speed might not be acceptable for the fruit handling systems of the future. Concerning fill uniformity, there was some mounding in the center and under fill in the corners, which required manual filling of corners at certain fill stages. The reason for the center mounding and corner under fill occurred during this experiment was that waxed fruit were used. The wax created a sticky, tacky surface on the fruit, which prevented the fruit from gently sliding and rolling into the corners of the bin. This problem was reduced by adjusting the tray indexing sensors to pack the tray more tightly with fruit. Then, when the tray dump cycle was completed, the center mounding and corner under fill problem was reduced. Consequently, the evaluators considered this a minor issue that could be corrected with adjustments to the tray indexing sensors.

Table 7 provides a summary of the performance of the bin filler with respect to fruit damage. Fruit quality was generally very good with Extra Fancy grade ranging (depending on

Table 4. Fruit firmness and maturity of apples, Experiment 2.

Cultivar	Firmness (N)[a][b]	Starch Index[c]
Delicious	68.2a	6.0
Golden Delicious	74.7b	6.2
Mutsu	50.7c	6.1

[a] Readings taken with a hand-held Effegi penetrometer fitted with an 11-mm tip.
[b] Mean separation within columns by Duncan's multiple range test, P = 0.05.
[c] Harvest criteria: 1-3 is immature, 4-6 is mature, and 7-9 overmature.

Table 5. Fruit grade classification at various sampling locations after moving through the dry bin filler, Experiment 2.

Cultivar	Location of Sample	Extra Fancy[a] Classes 1-4 (%)	Fancy Class 5 (%)	Downgraded Due to Bruises Class 6 (%)	Downgraded Due to Cuts & Punctures Class 7 (%)
Delicious	Fruit accumulation stage	99.0	1.0	0	0
	Top third of bin	100.0	0	0	0
	Middle third of bin	97.0	1.5	1.5	0
	Bottom third of bin	100.0	0	0	0
Golden Delicious	Fruit accumulation stage	98.9	1.1	0	0
	Top third of bin	98.9	0	1.1	0
	Middle third of bin	100.0	0	0	0
	Bottom third of bin	100.0	0	0	0
Mutsu	Fruit accumulation stage	98.0	1.0	1.0	0
	Top third of bin	98.0	1.0	1.0	0
	Middle third of bin	98.0	1.0	1.0	0
	Bottom third of bin	96.0	1.0	3.0	0

[a] Grade classes described in table 1. Mean separation within columns and cultivars by Duncan's multiple range test, P = 0.05. No significant differences for grades across cultivars or sampling locations, P = 0.05.

Table 6. Detailed breakdown of Extra Fancy apples following dry bin filler handling, Experiment 2.

Cultivar	Location of Sample	Class 1[a] (%)	Class 2 (%)	Class 3 (%)	Class 4 (%)
Delicious	Fruit accumulation stage	97.5	1.5	0	0
	Top third of bin	96.4	3.6	0	0
	Middle third of bin	97.4	1.5	0	0
	Bottom third of bin	99.5	0.5	0	0
Golden Delicious	Fruit accumulation stage	94.8	4.2	0	0
	Top third of bin	98.9	0	0	0
	Middle third of bin	96.7	2.2	0	1.1
	Bottom third of bin	97.8	0	0	2.2
Mutsu	Fruit accumulation stage	94.0a	3.0a	0	1.0
	Top third of bin	83.5b	10.4b	3.1	1.0
	Middle third of bin	89.0ab	7.0ab	1.0	1.0
	Bottom third of bin	86.0ab	8.0ab	1.0	1.0

[a] Mean separation within columns and cultivars by Duncan's multiple range test, P = 0.05. Bruising significantly greater on Mutsu than on either Delicious or Golden Delicious; no significant differences for bruising among sampling locations, P = 0.05.

Table 7. Fruit grade classification at various sampling locations after moving through the dry bin filler, Experiment 3.

Cultivar	Location of Sample	Extra Fancy[a] Classes 1–4 (%)	Fancy Class 5 (%)	Downgraded Due to Bruises Class 6 (%)	Downgraded Due to Cuts and Punctures Class 7 (%)
Golden Delicious	Bottom layer of bin	87	9.5	2	1.5
	Bottom quarter of bin	98	1	0	(1)[b]
	Middle layer of bin	99	1	0	0
	Top quarter layer of bin	97	1	0	(2)
Golden Delicious	Bottom layer of bin	92	4	2	1
	Bottom quarter of bin	100	0	0	0
	Middle layer of bin	96	2	0	(2)
	Top quarter layer of bin	99	1	0	0
Fuji	Bottom layer of bin	95	5	0	0
	Bottom quarter of bin	98			(2)
	Middle layer of bin	100	0	0	0
	Top quarter layer of bin	100	0	0	0
Fuji	Bottom layer of bin	95	0	0	(5)
	Bottom quarter of bin	97	0	0	(3)
	Middle layer of bin	100	0	0	0
	Top quarter layer of bin	99	1	0	0

[a] Grade classes described in table 1. Fruit from bottom layer of bin downgraded more that fruit from other layers based on mean separation across cultivars by Duncan's multiple range test, P= 0.05.

[b] Cuts caused by bin filler rods.

cultivar) from 87% to 95% for fruit collected from the bottom of the bin to 96% to 100% for fruit collected from the middle layer of the bin. Punctures and cuts from the bin filler rods ranged from 0 to 5%. The firmness of the 'Golden Delicious' fruit was 48 to 53 N, and the firmness of the 'Fuji' was 75 to 79 N (data not shown), as measured with a Magness Taylor penetrometer fitted with an 11-mm tip, and the fruit demonstrated moderate susceptibility to bruising.

Commercial evaluations with an Impact Recording Device (Techmark, Inc., Lansing, Mich.; previously referred to as an instrumented sphere) also were conducted at Double Diamond Fruit. The Impact Recording Device is a "mechanical" apple that can be moved through a fruit handling system to identify the location and severity of potential sites of impact. Severity is calculated using both maximum acceleration and velocity of each impact. The Impact Recording Device was moved through a conventional bin filler used by the packinghouse and also through the USDA dry bin filler, and the data provided additional documentation of the gentle handling properties of the USDA dry bin filler. Whereas bruise damage from currently used dry bin fillers ranges as high as 8%, bruise injury from the USDA dry bin filler was less than 5%, and this difference in the potential to bruise fruit was verified by the Impact Recording Device.

Conclusions

Research trials and commercial assessments of a USDA dry bin filler indicated that the new sequenced tray handling concept of the bin filler described in this article reduces the potential for bruise damage to apple fruit. Following bin handling, fruit downgraded from U.S. Extra Fancy due to bruising averaged 1.7%, 1.4%, and 2.9% in replicated experiments at a USDA research facility, a Pennsylvania packinghouse, and a Washington State packinghouse, respectively. Fruit damage on eight cultivars under varying test conditions was less than the 5% desired industry threshold. Current dry bin fillers generally cause bruising on 8% of the fruit of a bruise susceptible cultivar such as 'Golden Delicious.' A possible improvement to the filler would be to shorten the tray travel time. In addition, future engineering efforts should be directed toward developing an in-field dry bin filler that will facilitate assisted harvest operations.

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